

# Solar Eclipses: What They Are, Front Line Experiences, and Some Science

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# Today's Discussion:

- Overview of eclipses.
- The 21 August 2017 total solar eclipse.
- Eye safety.
- A couple of experiences from the “front line” of past eclipses.
- The motivation for doing solar eclipse studies (just an outline...).
- Things you can do.

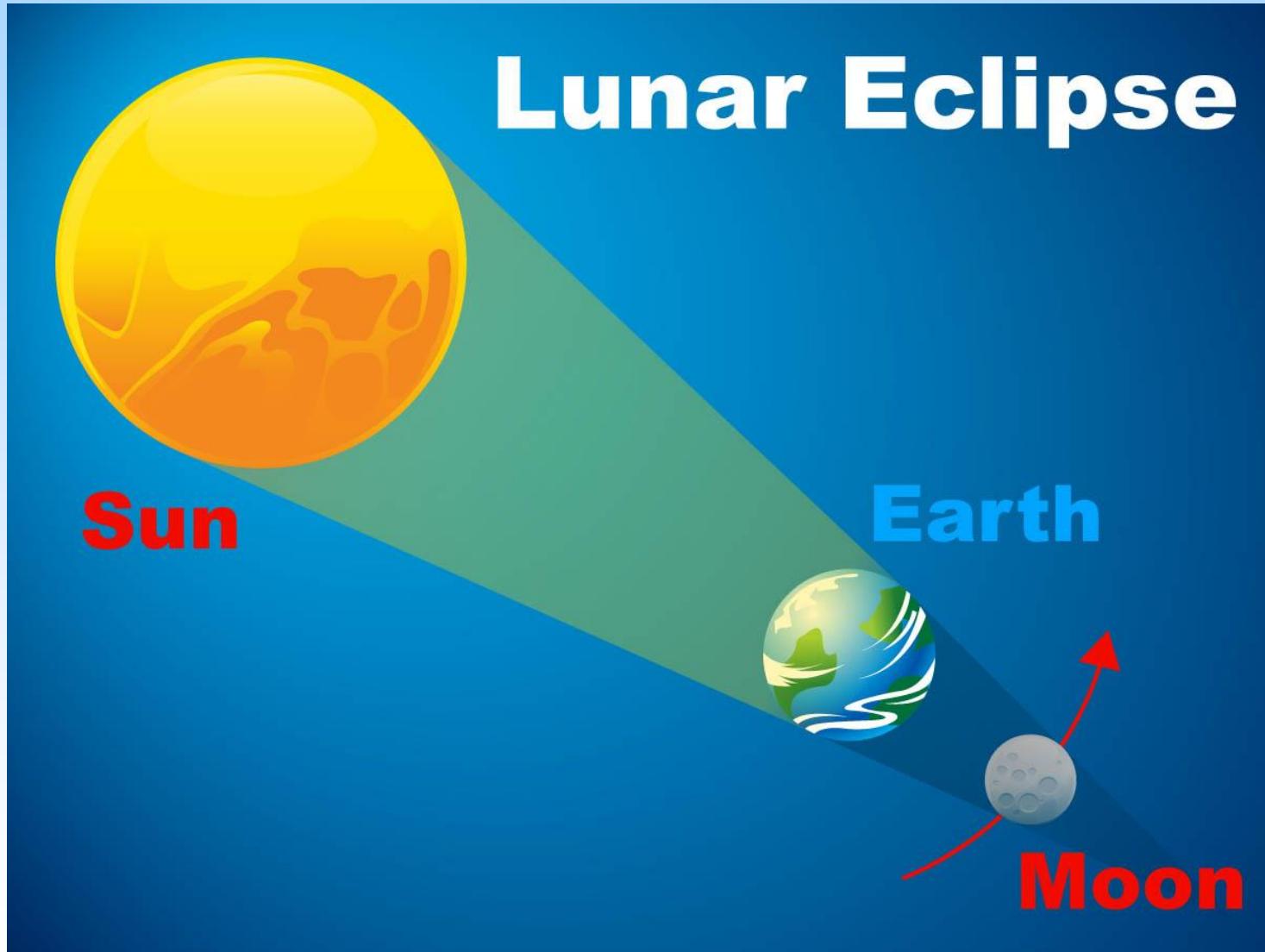
# What are Eclipses?

- One body falls into the shadow of another.

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- One body falls into the shadow of another.
- Lunar eclipses.

# Lunar Eclipse



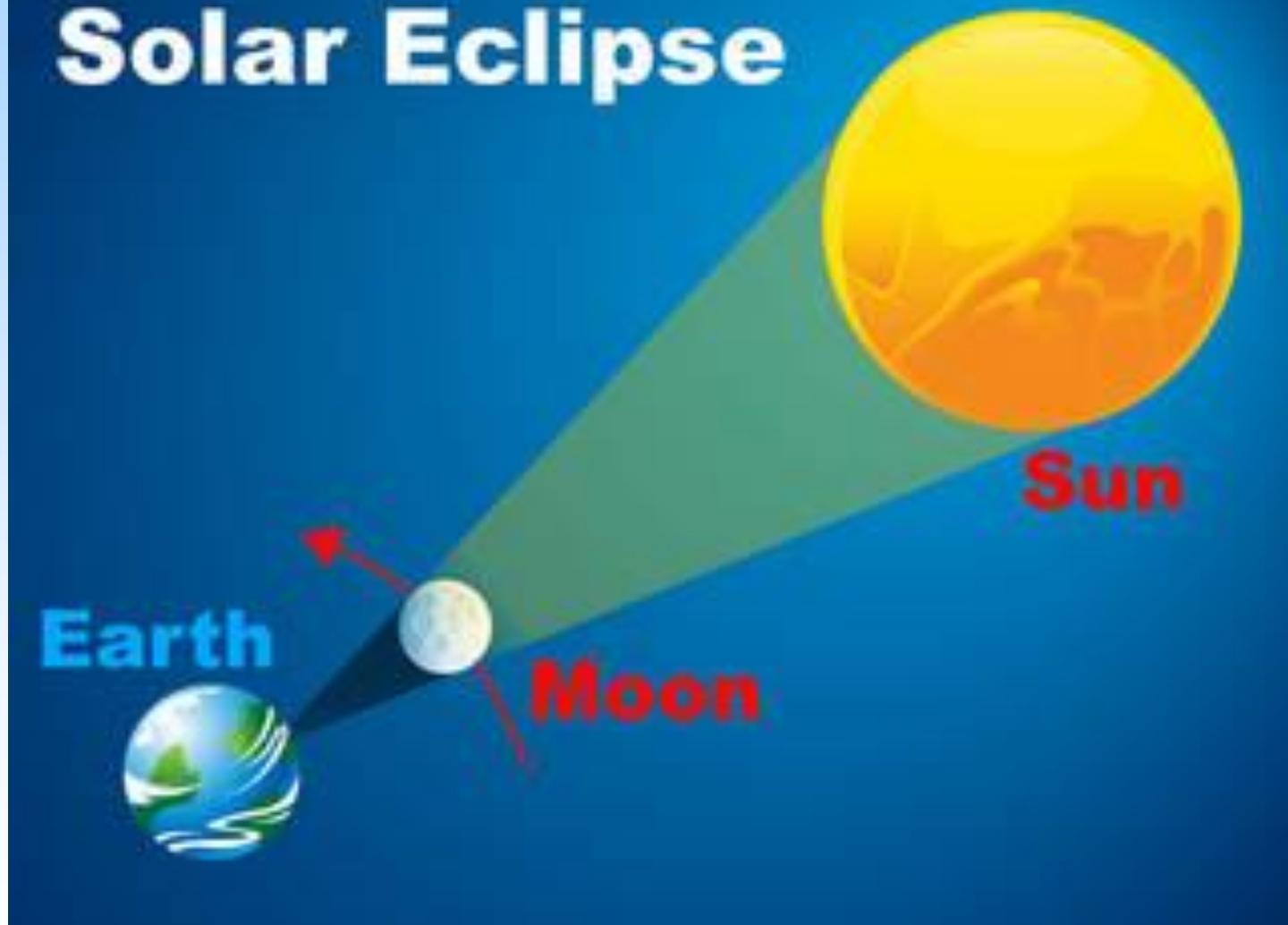
# What are Eclipses?

- One body falls into the shadow of another.
- Lunar eclipses.
- Solar eclipses.

# What are Eclipses?

- One body falls into the shadow of another.
- Lunar eclipses.
- Solar eclipses.
  - Partial.
  - Annular.
  - Total.

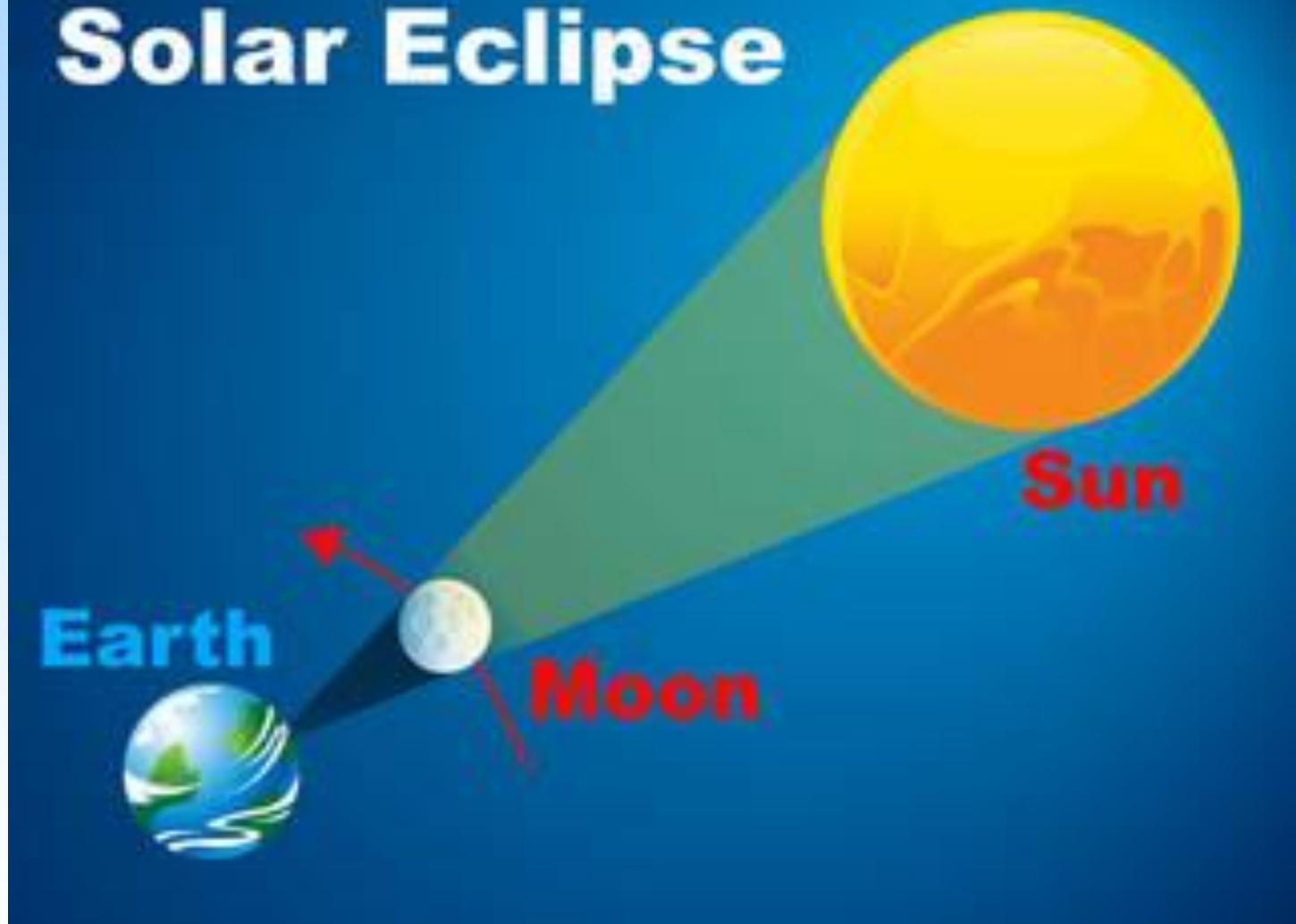
# Solar Eclipse



The moon's orbit is tilted.



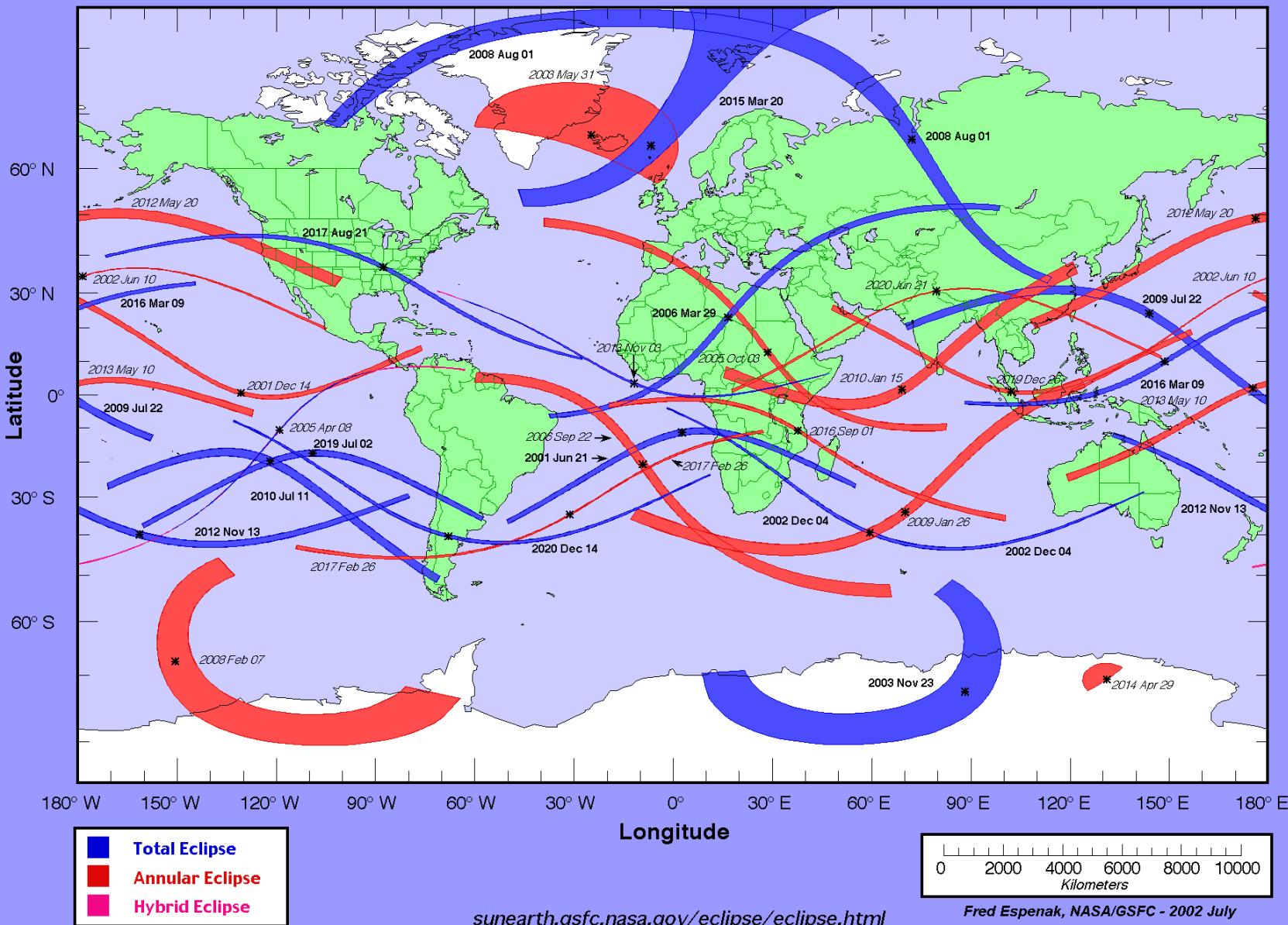
# Solar Eclipse





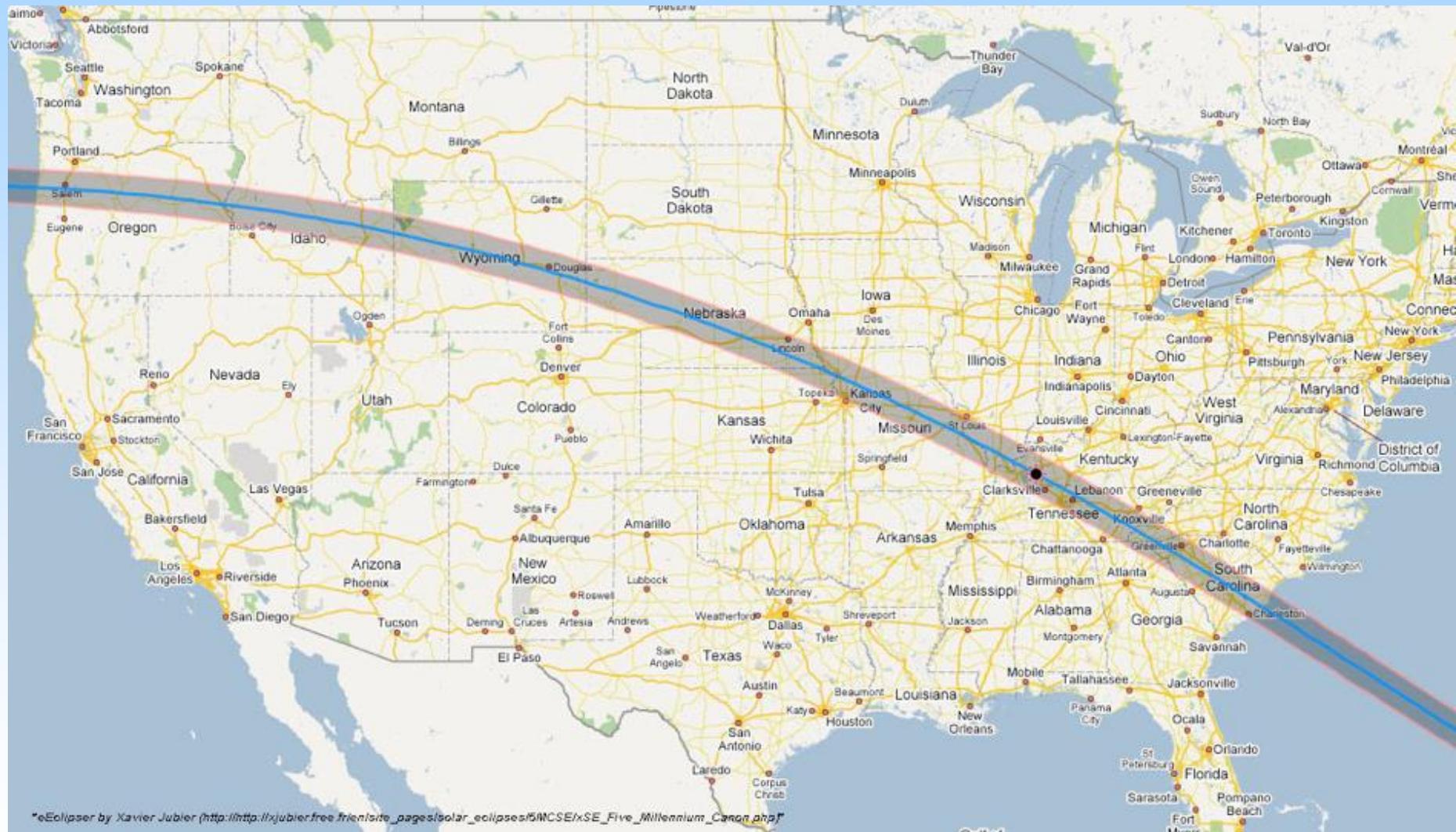
20 May 2012 22:35:02 UT

# Total and Annular Solar Eclipse Paths: 2001 – 2020



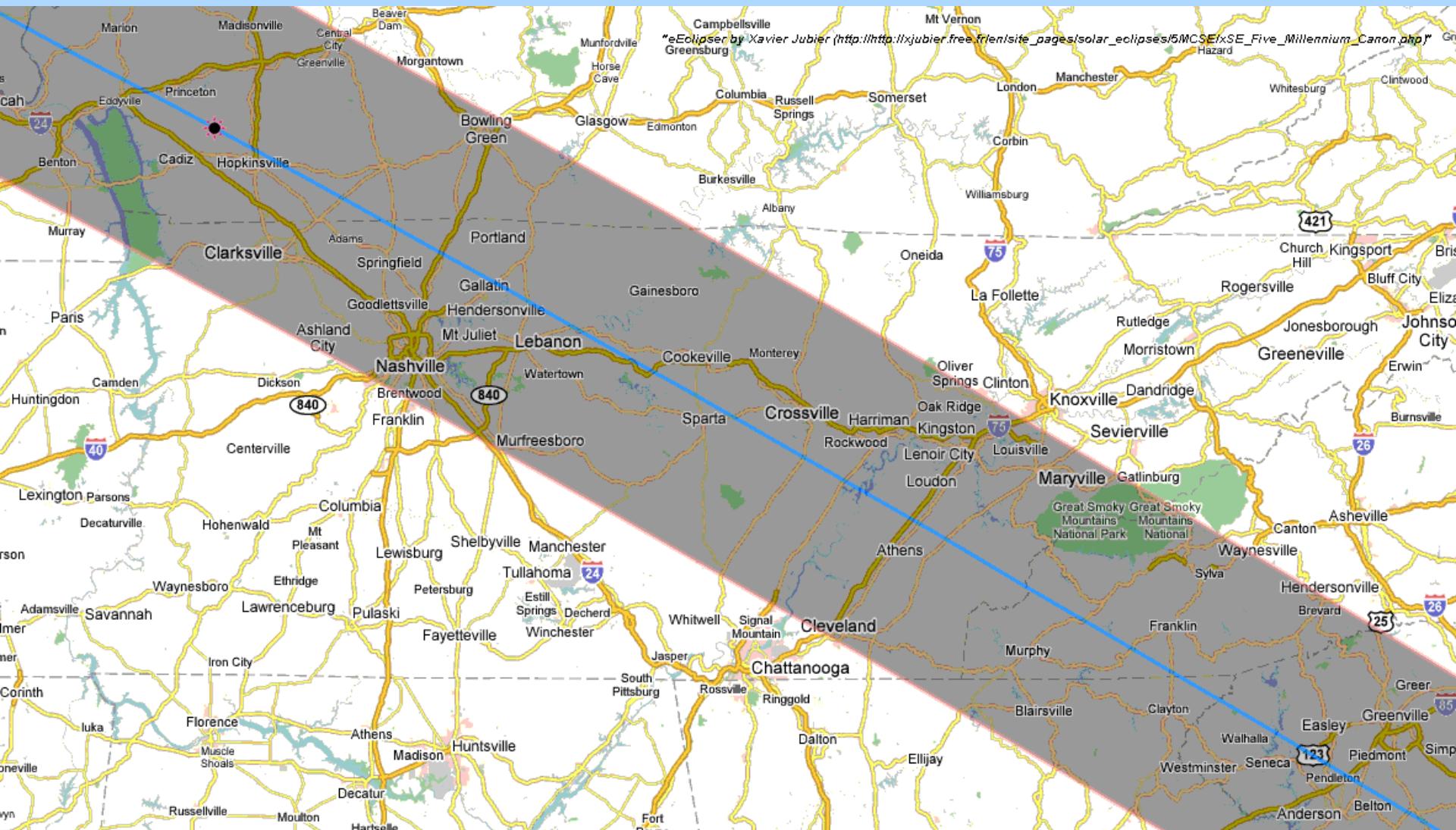
# The 21 August 2017 Total Solar Eclipse

# August 21, 2017 Total Solar Eclipse Path



\*eEclipses by Xavier Jubier ([http://xjubier.free.fr/enSite\\_pages/solar\\_eclipses/5MCSE/xSE\\_Five\\_Millennium\\_Canonical.php](http://xjubier.free.fr/enSite_pages/solar_eclipses/5MCSE/xSE_Five_Millennium_Canonical.php))

# August 21, 2017 Total Solar Eclipse Path



# Do not Risk Your Precious Eyes!!

- Do *not* look at the partial phases of the eclipse directly without certified eye protection!!
- There's no point to staring at partial phases....
- Look without protection only if you're in the totality path, and then only during totality! (About 2 minutes.)

# Viewing Eclipses (partial phases)

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- Eclipse glasses:  
(<https://eclipse.aas.org/resources/solar-filters>)



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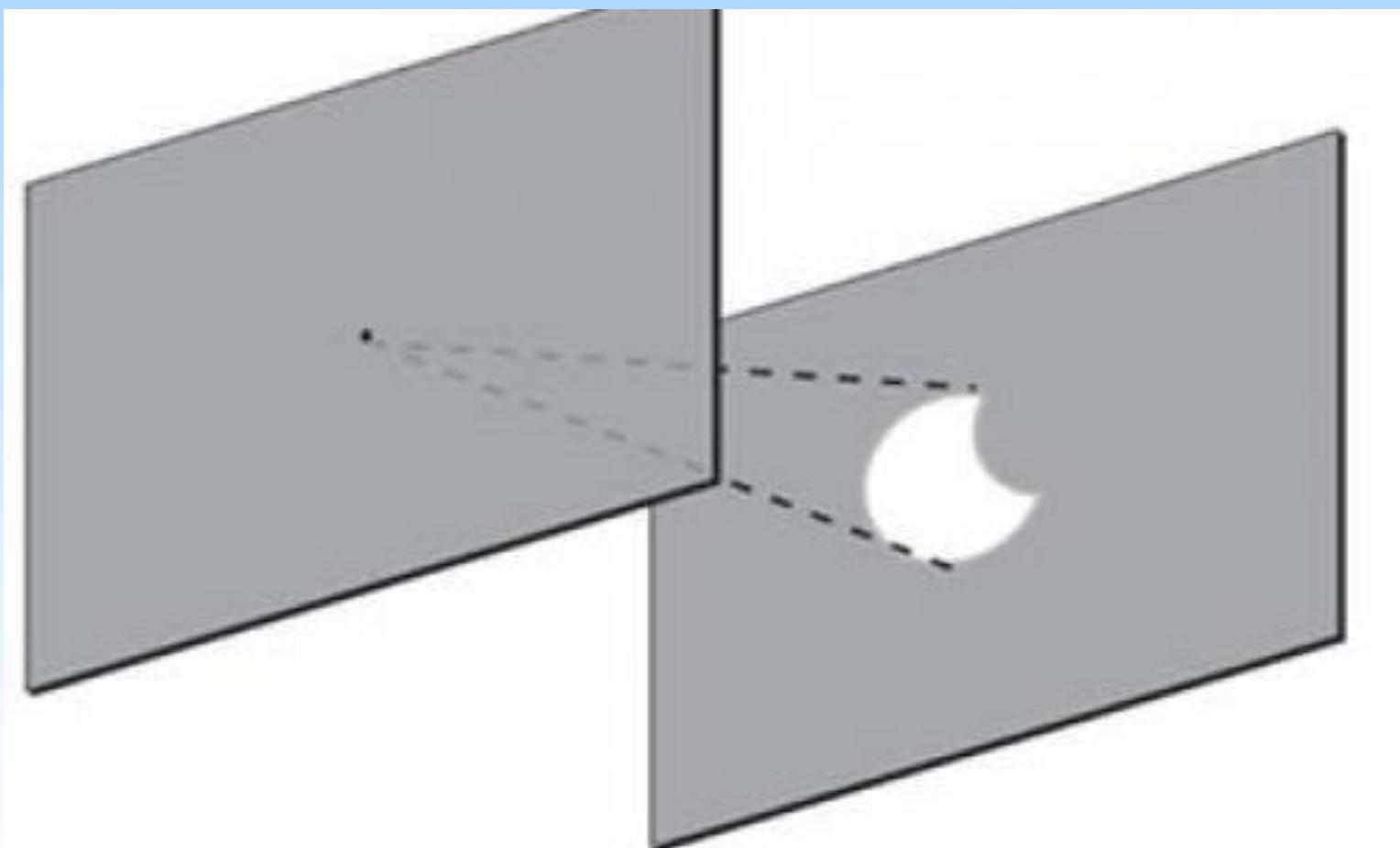
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# Viewing Eclipses (partial phases)

- Eclipse glasses
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- Indirect methods
  - Pinhole projection
  - Box projection

## MAKE YOUR OWN CARDBOARD PROJECTOR

You can make this simple eclipse projector with some cardboard, paper, tape and foil.

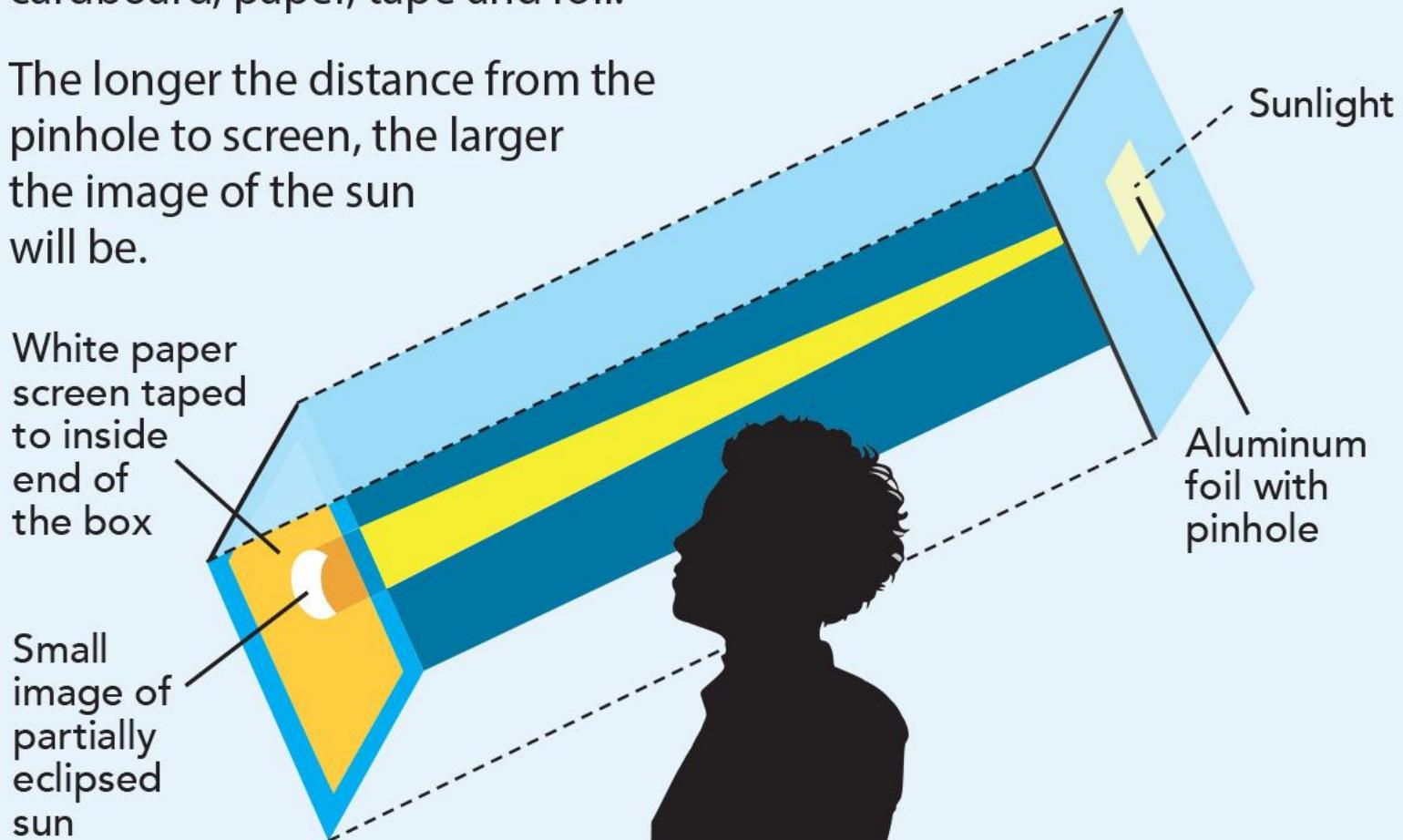
The longer the distance from the pinhole to screen, the larger the image of the sun will be.

White paper screen taped to inside end of the box

Small image of partially eclipsed sun

Sunlight

Aluminum foil with pinhole



# Viewing Eclipses (partial phases)

- Eclipse glasses
- Welder's glass (#14)
- Indirect methods
  - Pinhole projection
  - Box projection
  - Telescope/binocular projection

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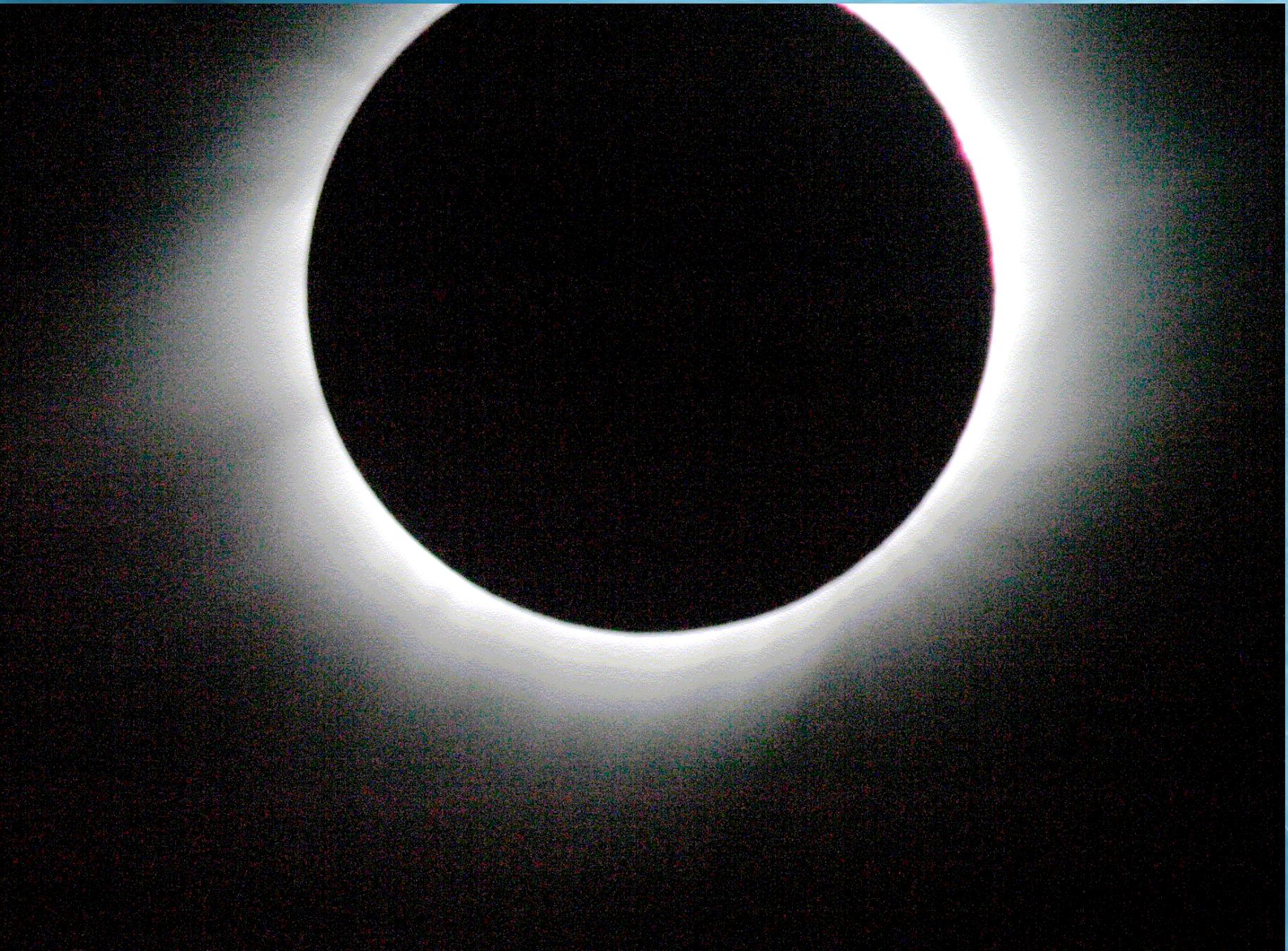
- Eclipse glasses
- Welder's glass (#14)
- Indirect methods
  - Pinhole projection
  - Box projection
  - Telescope/binocular projection
  - Almost-anything projection!

# Eclipse Science

# *How Not* to do Eclipse Science! Ghana 2006 Version

(Useful information for picture takers too.)









# Lessons Learned (Science at Eclipses)

- 💡 No new equipment.
- 💡 Consider carefully before moving after setting up.
- 💡 Practice, practice, practice!



Gansu Province, China, 2008











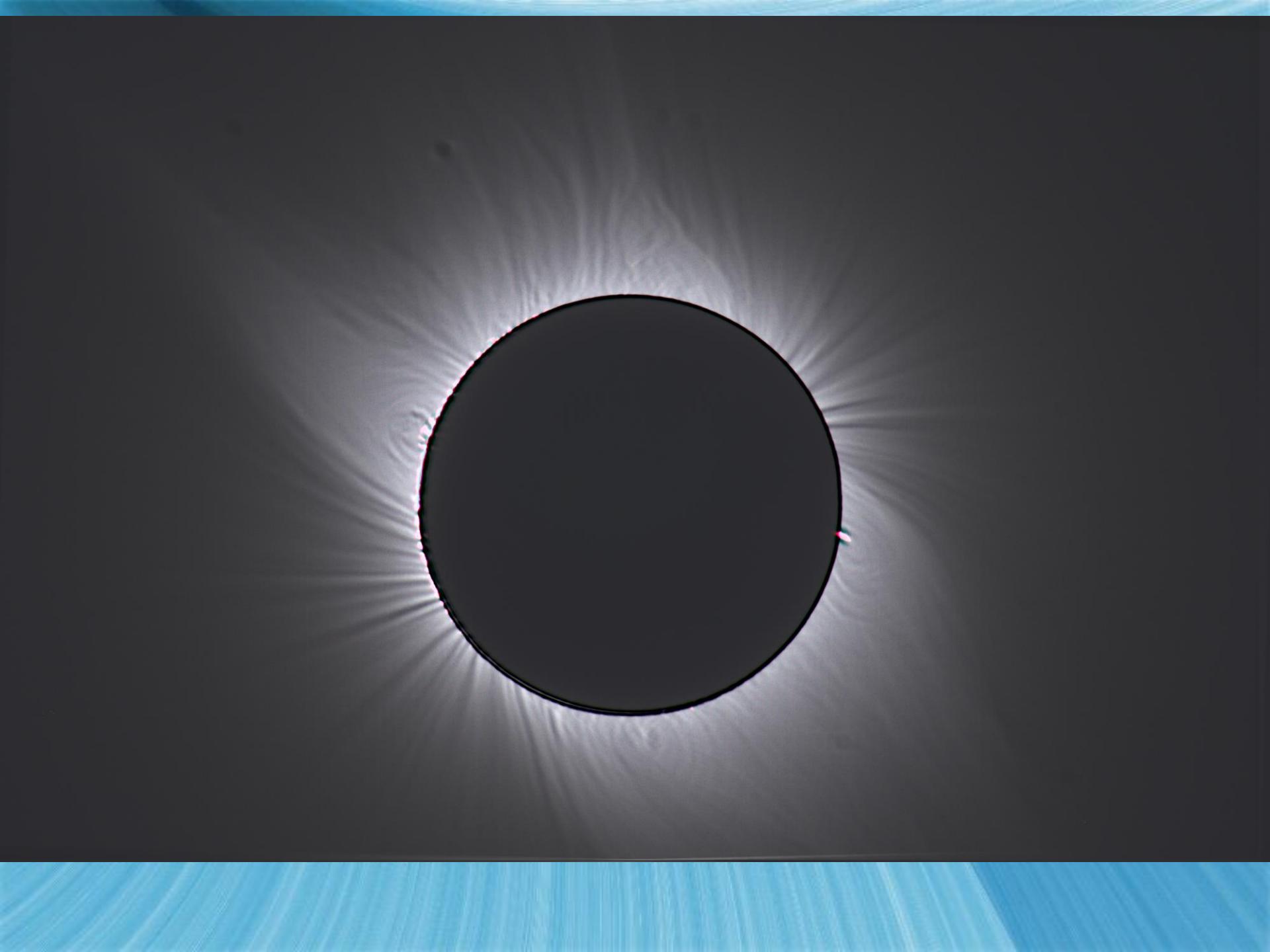








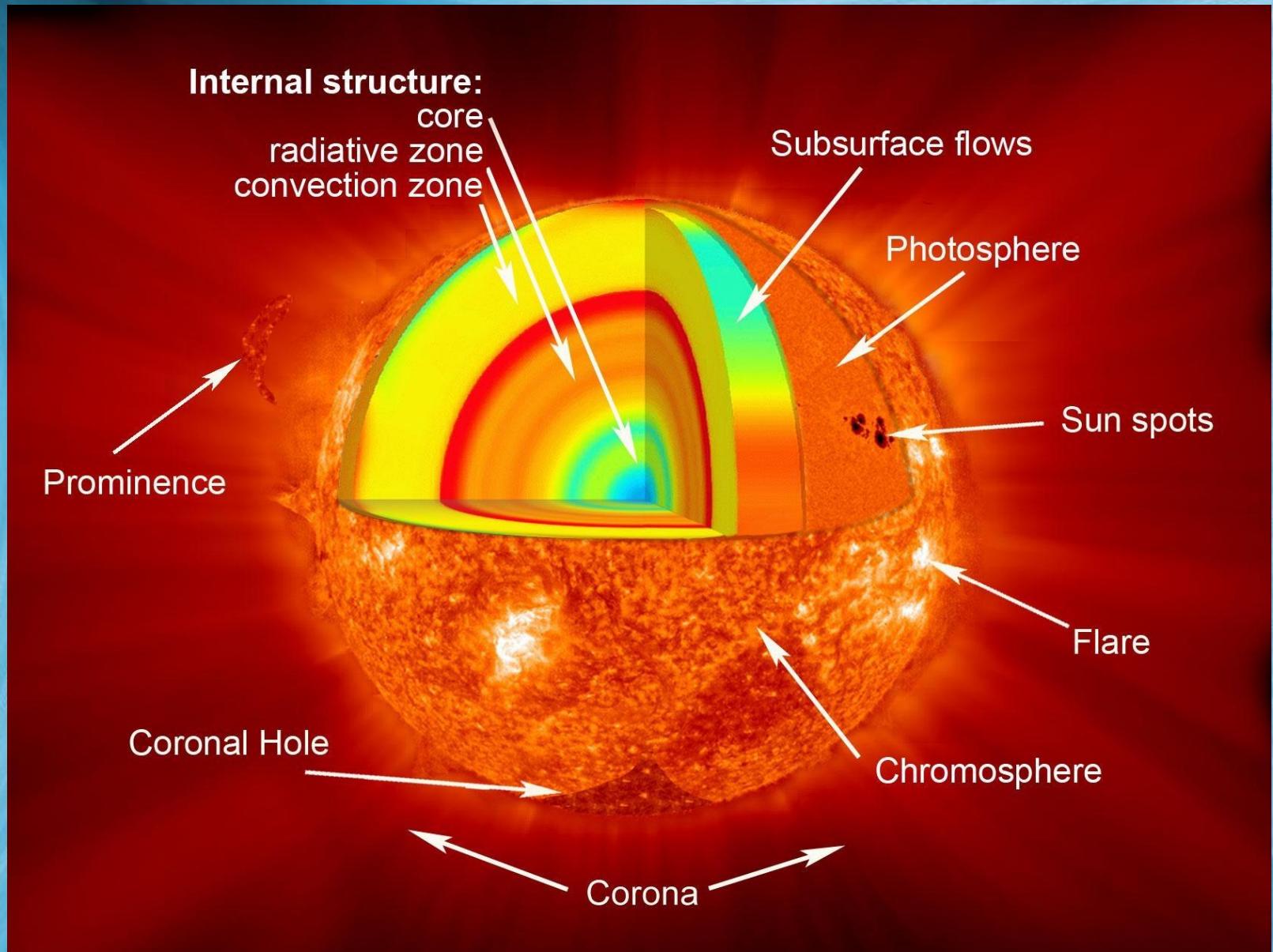


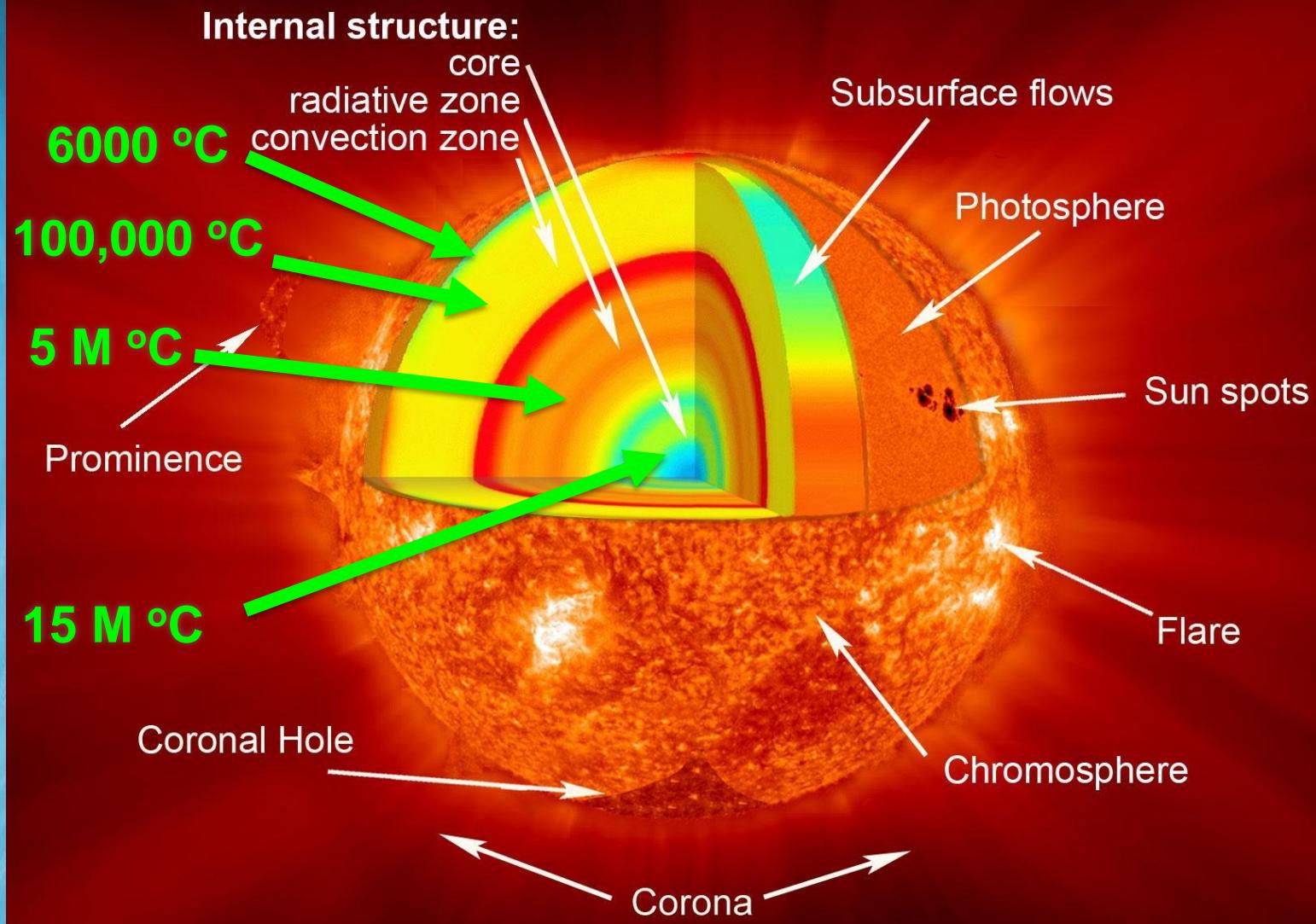






# Science of the Sun. A key Problem: The Temperature of the Corona

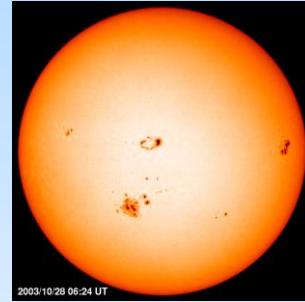




# The Solar Atmosphere

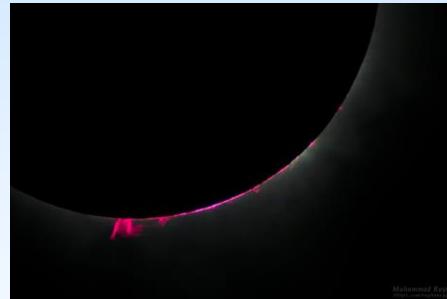
The Outer layers (Atmospheres) of the Sun:

- Photosphere



2003/10/28 06:24 UT

- Chromosphere



Mahmoud Rayhan  
image: sunspotmonitor.com

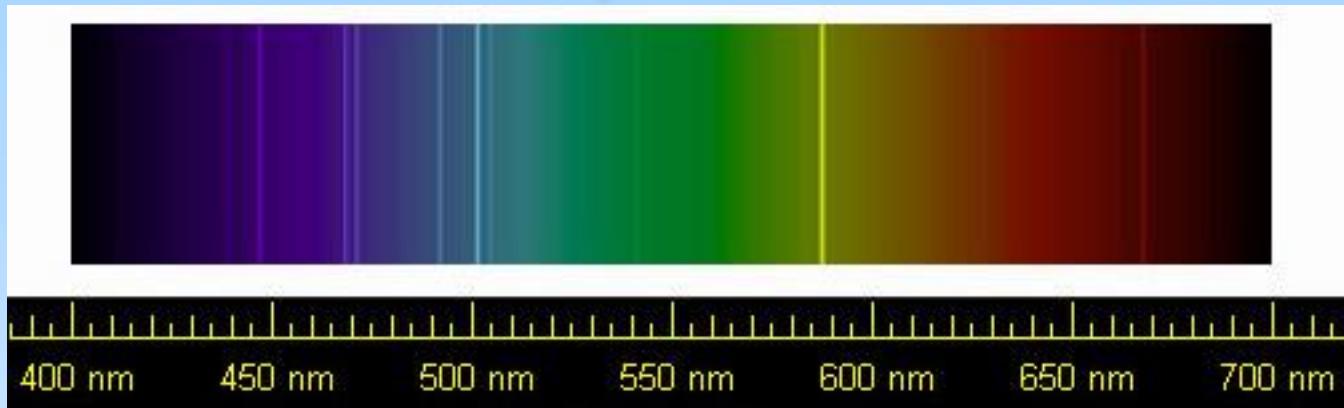
- Corona



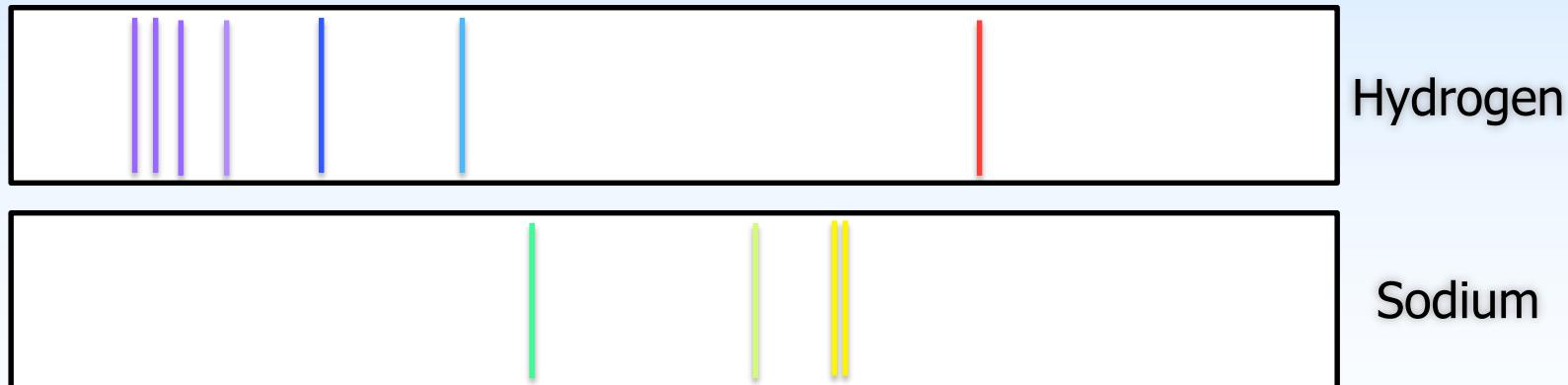
# But....

- A “problem” resulted from 1869 eclipse observations of the corona.
- Used a recently developed instrument - the “spectroscope,” to study the corona.

# Spectra



- Breaks light into “rainbow” colors, with lines.
- Different elements produce different lines.
- So these lines are like “fingerprints” for elements.



- Hence, spectra can be used to determine the composition of far-away objects, like the corona.

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But this didn’t work....

# The Periodic Table

**Legend:**

- Metals:** Gray
- Non-metals:** Green
- Alkali Metals:** Yellow-green
- Alkali Earth Metals:** Light green
- Transition Metals:** Blue
- Lanthanoids:** Yellow
- Actinoids:** Orange
- Metalloids:** Red
- Halogens:** Gold
- Noble Gases:** Purple
- Hydrogen:** White

**Standard Atomic Weight:** Values in parentheses indicate standard atomic weight.

Element	Atomic Number	Symbol	Name	Standard Atomic Weight
Hydrogen	1	H	hydrogen	1.007 9(7)
Helium	2	He	helium	4.002 6(2)
Lithium	3	Li	lithium	6.941(1)
Boron	4	Be	boron	10.012 8(3)
Sodium	11	Na	sodium	22.989 76(4)
Magnesium	12	Mg	magnesium	24.305 0(4)
Potassium	19	K	potassium	39.098 9(4)
Calcium	20	Ca	calcium	40.078 9(4)
Scanium	21	Sc	scaniun	44.955 6(4)
Titanium	22	Ti	titanium	47.867(4)
Vanadium	23	V	vanadium	50.941 8(3)
Chromium	24	Cr	chromium	51.996 1(3)
Manganese	25	Mn	manganese	54.938 0(4)
Iron	26	Fe	iron	55.845 0(4)
Cobalt	27	Co	cobalt	58.931 4(2)
Nickel	28	Ni	nickel	58.693 4(2)
Copper	29	Cu	copper	63.546 9(2)
Zinc	30	Zn	zinc	65.402 8(2)
Gallium	31	Ga	gallium	69.721 0(2)
Silicon	13	Si	silicon	28.085 7(2)
Phosphorus	14	P	phosphorus	30.973 7(2)
Sulfur	15	S	sulfur	32.065 6(2)
Chlorine	16	Cl	chlorine	35.453 2(2)
Argon	18	Ar	argon	39.902 4(1)
Rubidium	37	Rb	rubidium	85.469 3(3)
Sternum	38	Sr	strontium	87.630 1(2)
Yttrium	39	Y	yttrium	88.905 5(2)
Zirconium	40	Zr	zirconium	91.224 3(2)
Niobium	41	Nb	niobium	92.906 2(2)
Molybdenum	42	Mo	molybdenum	95.940 2(2)
Techneium	43	Tc	technetium	98.905 2(2)
Ruthenium	44	Ru	ruthenium	101.092 7(2)
Rhodium	45	Rh	rhodium	102.905 0(2)
Palladium	46	Pd	palladium	106.425 8(2)
Silver	47	Ag	silver	107.868 1(2)
Cadmium	48	Cd	cadmium	112.451 6(2)
Inertium	49	In	inertium	114.845 1(2)
Tin	50	Sn	tin	118.780 1(2)
Antimony	51	Sb	antimony	121.769 1(2)
Tellurium	52	Te	tellurium	127.600 1(2)
Iodine	53	I	iodine	126.904 4(3)
Xenon	54	Xe	xenon	131.903 6(2)
Cesium	55	Cs	cesium	132.909 0(2)
Barium	56	Ba	barium	137.917 7(2)
Lanthanoids	57-71	La-Lu	lanthanoids	138.917(2)
Hafnium	72	Hf	hafnium	178.491 7(2)
Tantalum	73	Ta	tantalum	180.947 0(2)
Tungsten	74	W	tungsten	183.847 0(2)
Rhenium	75	Re	rhenium	190.902 1(2)
Osmium	76	Os	osmium	190.902 1(2)
Ruthenium	77	Ir	ruthenium	191.237 3(2)
Platinum	78	Pt	platinum	190.967 6(2)
Gold	79	Au	gold	196.967 6(2)
Mercury	80	Hg	mercury	200.592 0(2)
Thallium	81	Tl	thallium	204.392 0(2)
Lead	82	Pb	lead	207.212(2)
Bismuth	83	Bi	bismuth	210.007 4(2)
Poisonium	84	Po	poisonium	210(1)
ASTATINE	85	At	astatine	210(1)
RADIUM	86	Rn	radium	222(1)
Francium	87	Fr	francium	223(1)
Radium	88	Ra	radium	226(1)
Actinoids	89-103	Ac-Lr	actinoids	123(1)
Rutherfordium	104	Rf	rutherfordium	120(1)
Dubnium	105	Db	dubnium	126(1)
Sesborium	106	Sg	sesborium	126(1)
Bohrium	107	Bh	bohrium	127(1)
Hassium	108	Hs	hassium	127(1)
Meltinum	109	Mt	metinum	127(1)
Darmstadtium	110	Ds	darmstadtium	127(1)
Roentgenium	111	Rg	roentgenium	127(1)
Lanthanoids	57	La	lanthanum	139.909 47(1)
Cerium	58	Ce	cerium	140.087 69(1)
Praseodymium	59	Pr	praseodymium	140.907 69(1)
Neodymium	60	Nd	neodymium	140.907 69(1)
Prontecritium	61	Pm	prontecritium	141.907 69(1)
Samarium	62	Sm	samarium	140.907 69(1)
Euroopium	63	Eu	euroopium	141.907 69(1)
Gadolinium	64	Gd	gadolinium	147.976 0(1)
Terbium	65	Tb	terbium	147.976 0(1)
Dysprosium	66	Dy	dysprosium	149.963 3(2)
Holmium	67	Ho	holmium	149.963 3(2)
Erbium	68	Er	erbium	167.930 2(2)
Thulium	69	Tm	thulium	168.930 2(2)
Ytterbium	70	Yb	ytterbium	173.930 1(1)
Lu	71	Lu	lu	174.930 1(1)
Actinium	89	Ac	actinium	123(1)
Thorium	90	Th	thorium	124.003 6(2)
Protactinium	91	Pa	protactinium	124.055 3(1)
Uranium	92	U	uranium	123.928 9(2)
Neptunium	93	Np	neptunium	123(1)
Plutonium	94	Pu	plutonium	124(1)
Americium	95	Am	americium	124(1)
Curium	96	Cm	curium	124(1)
Berkelium	97	Bk	berkelium	124(1)
Californium	98	Cf	californium	125(1)
Einsteinium	99	Es	einsteinium	125(1)
Fermium	100	Fm	fermium	125(1)
Mendelevium	101	Md	mendelevium	126(1)
Noberium	102	No	noberium	126(1)
Lavrocium	103	Lr	lavrocium	126(1)

NASA/CXC/SAO



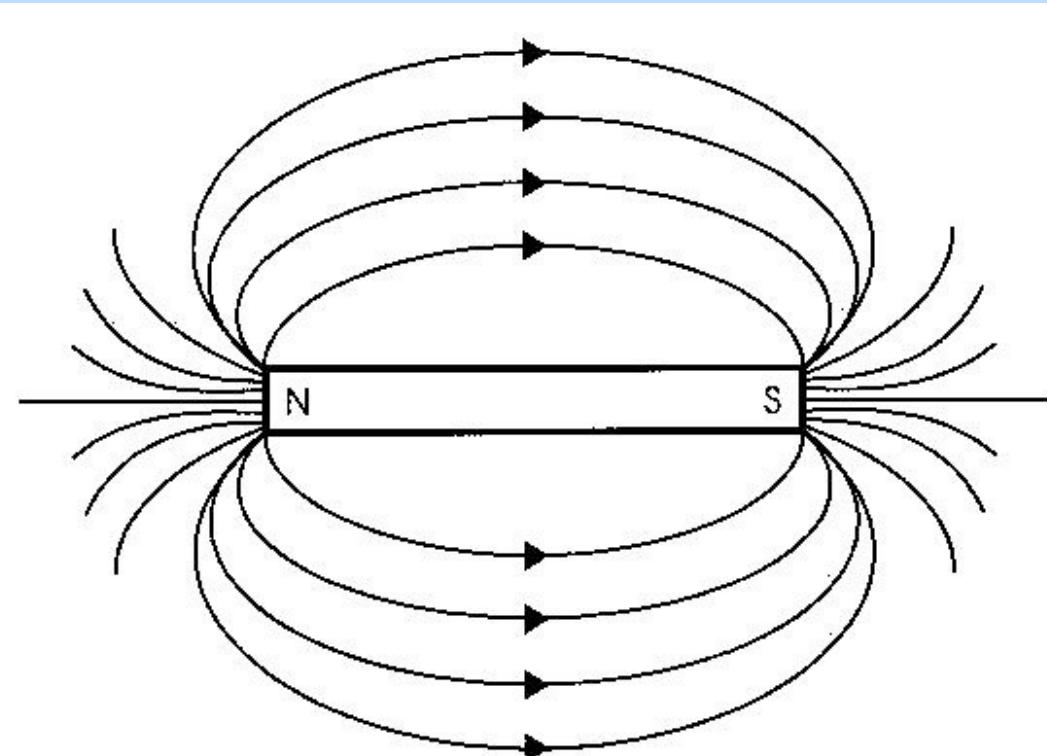
# The Corona: Continued...

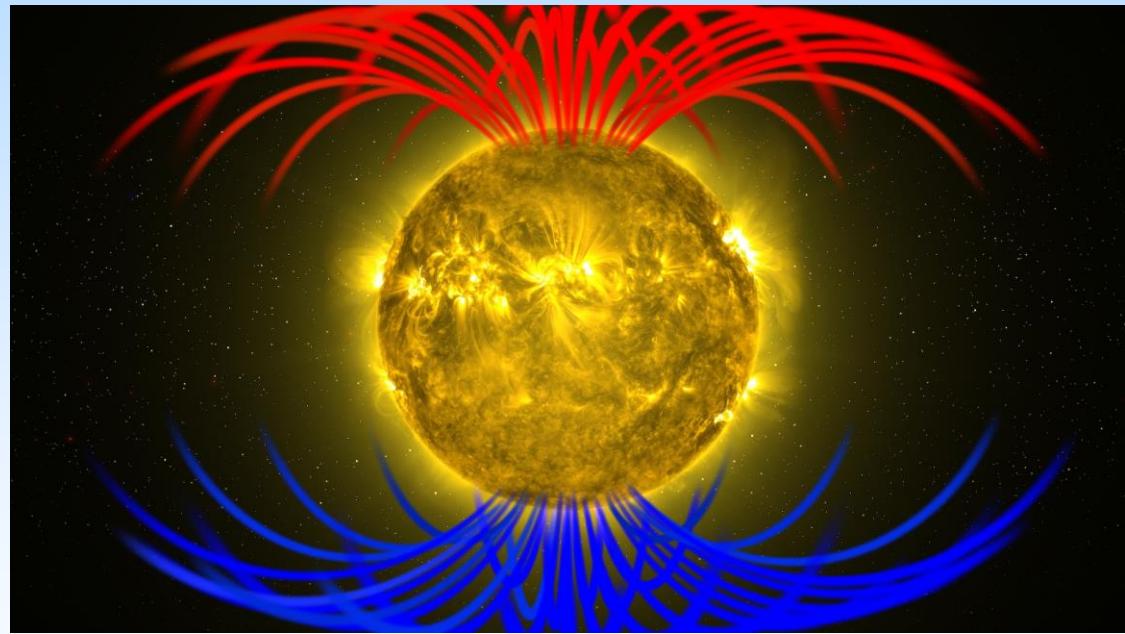
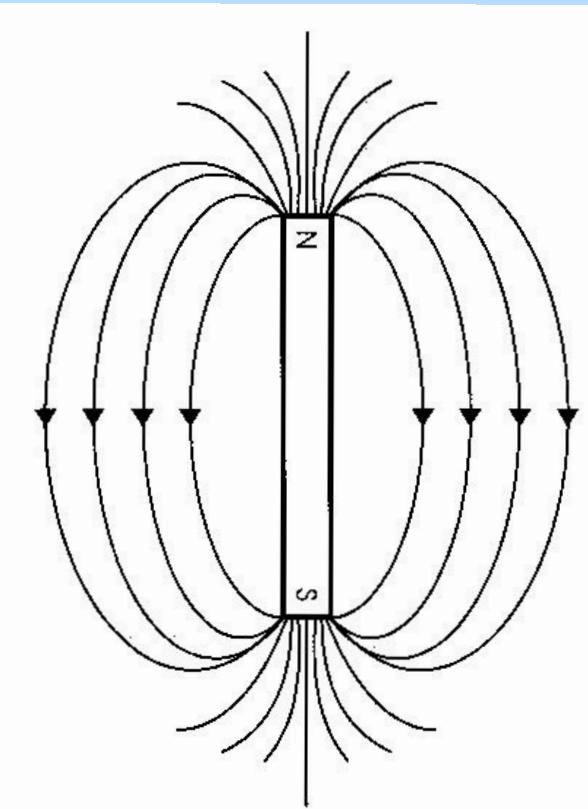
- The mystery spectral lines found to be due to very hot (“highly-ionized”) familiar elements ~1940.

So this was a sloooow process: 1869 eclipse observations, and 1939~1943 explanation!!

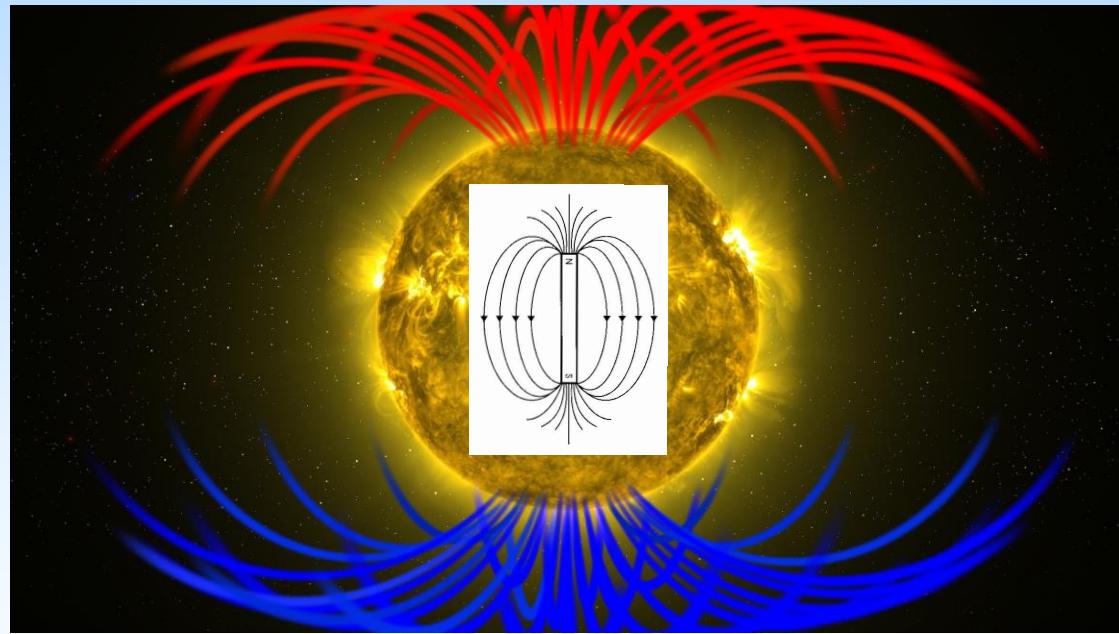
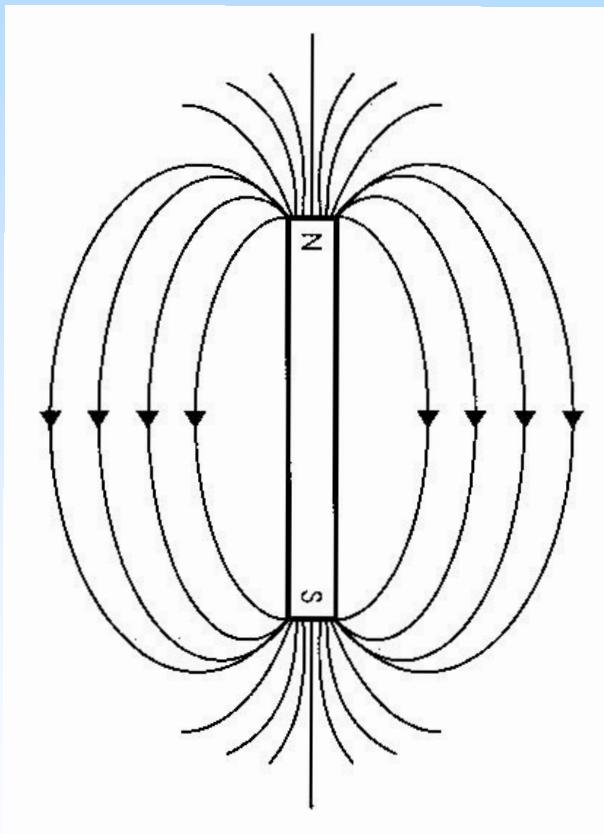
- Structure of the corona: late 1960s and 1970s observations from balloons, Skylab, etc.
- This structure due to the magnetic field.

**Magnetism** is the key to why the corona is hot. (It is also responsible for many of the changing features of the Sun.)

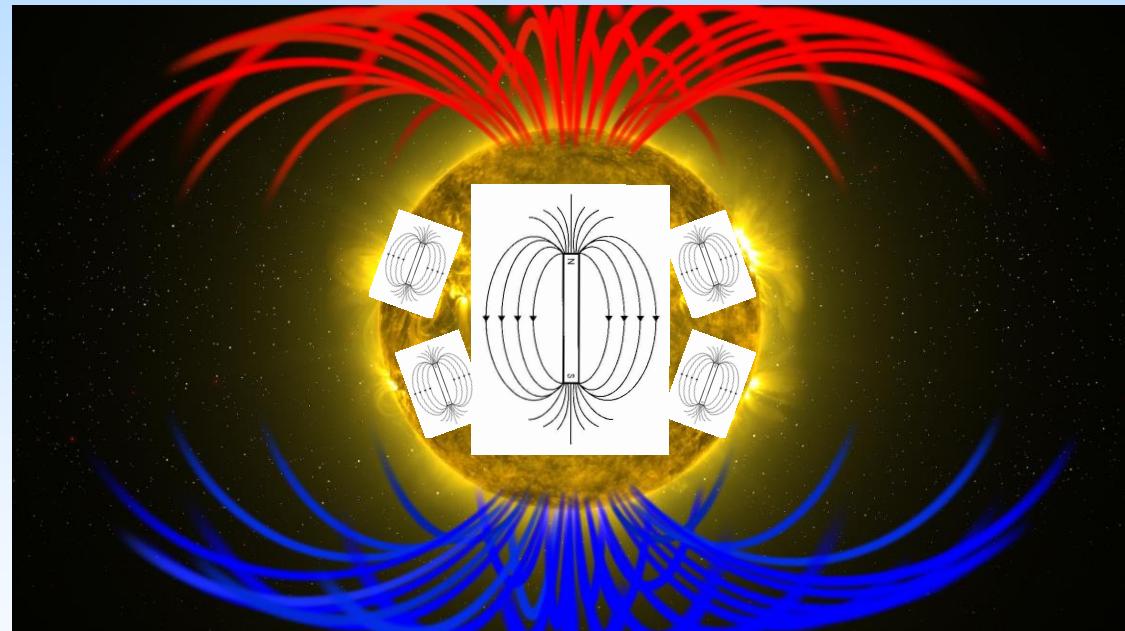
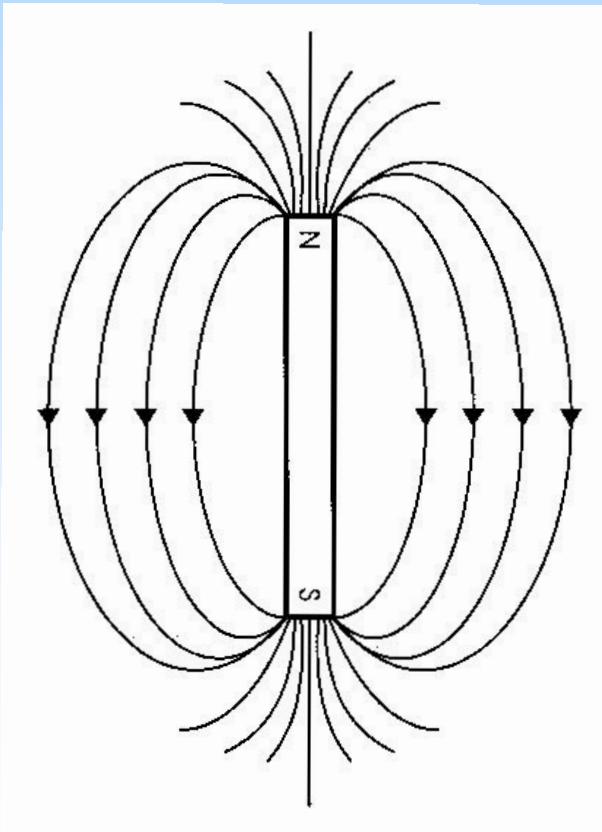


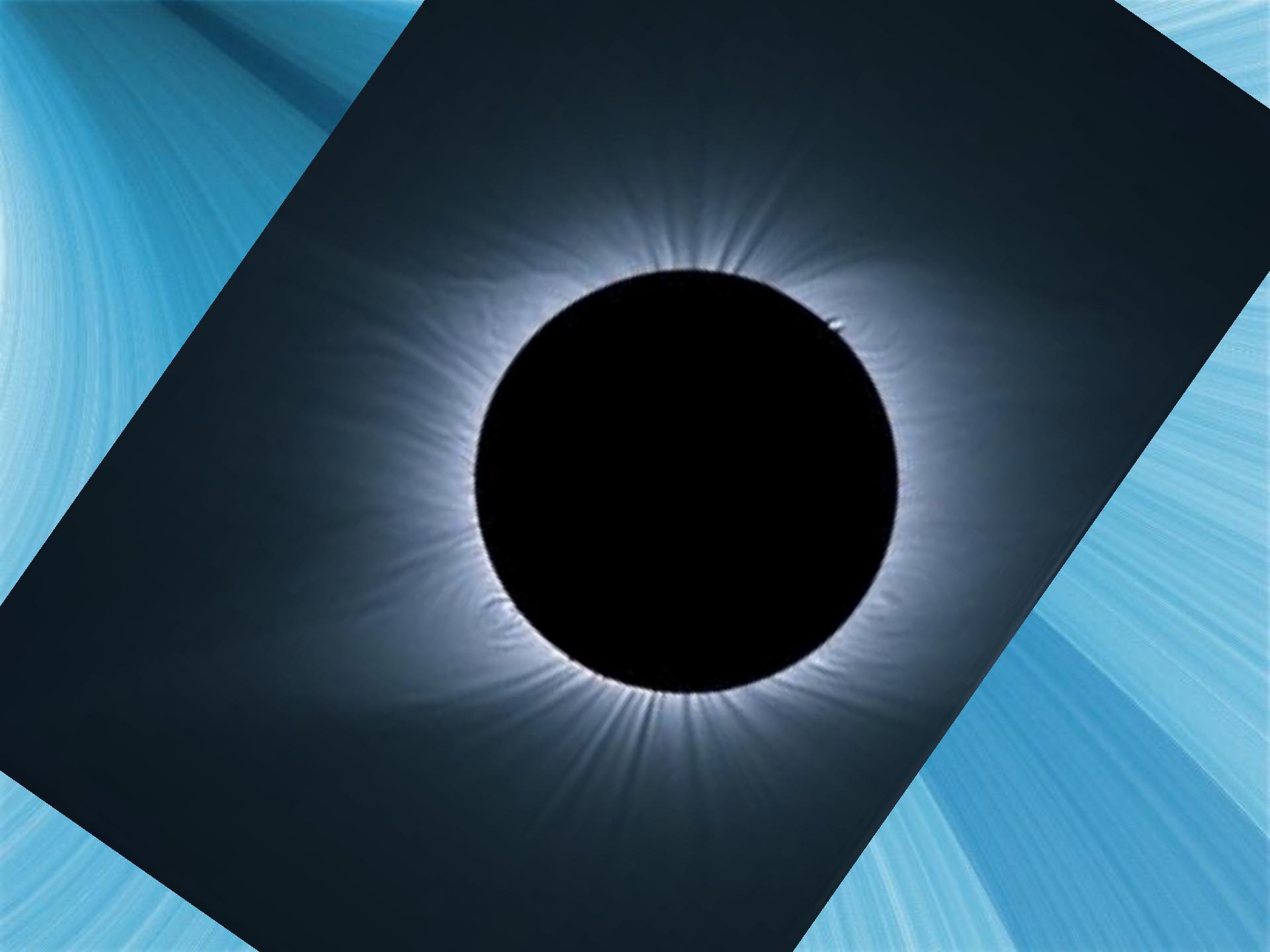


***Magnetism*** is the key to why the corona is hot.



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# A Key Objective of Solar Physics:

Unravel details of how the magnetic field heats the corona!

- This is one goal (direct or indirect) of many eclipse studies.
- Also, many other stars have hot coronae, and thus understanding the heating of the Sun's corona tells us about other stars too.



# Fun Things to Do:

- Temperature changes at different locations.
- Shadow bands, just near totality. Try taking pictures of them. (In path of totality.)
- Pictures of sharpening shadows. [To do “seriously”: Record time accurately (within a few seconds), your precise location (GPS coordinates?), use a standard surface (e.g., white sheet), sky conditions (may be hard unless clear).]
- Creative photography.

But maybe best of all...

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ENJOY IT!









PSQ-10

TAKAHASHI

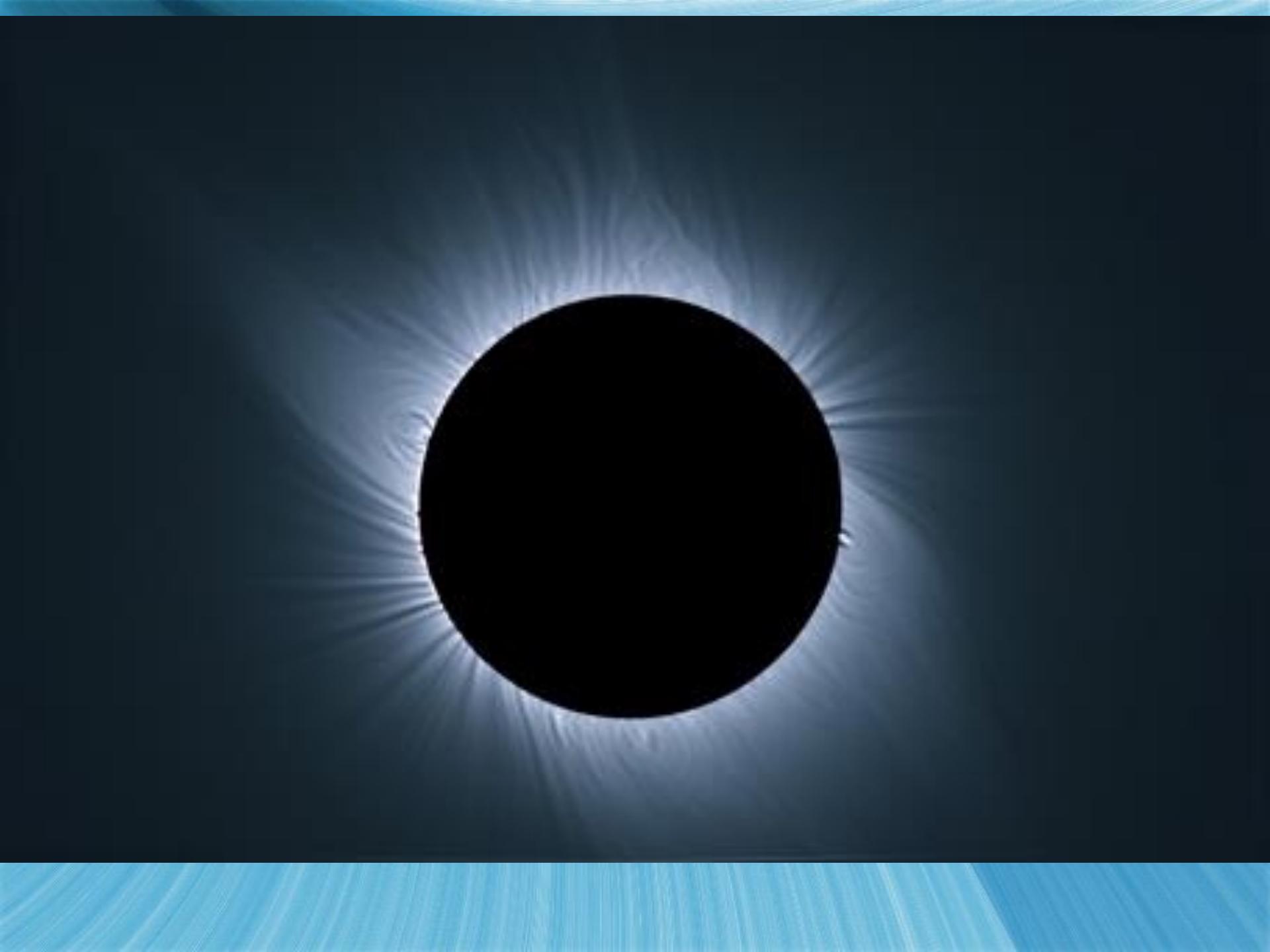
TAKAHASHI



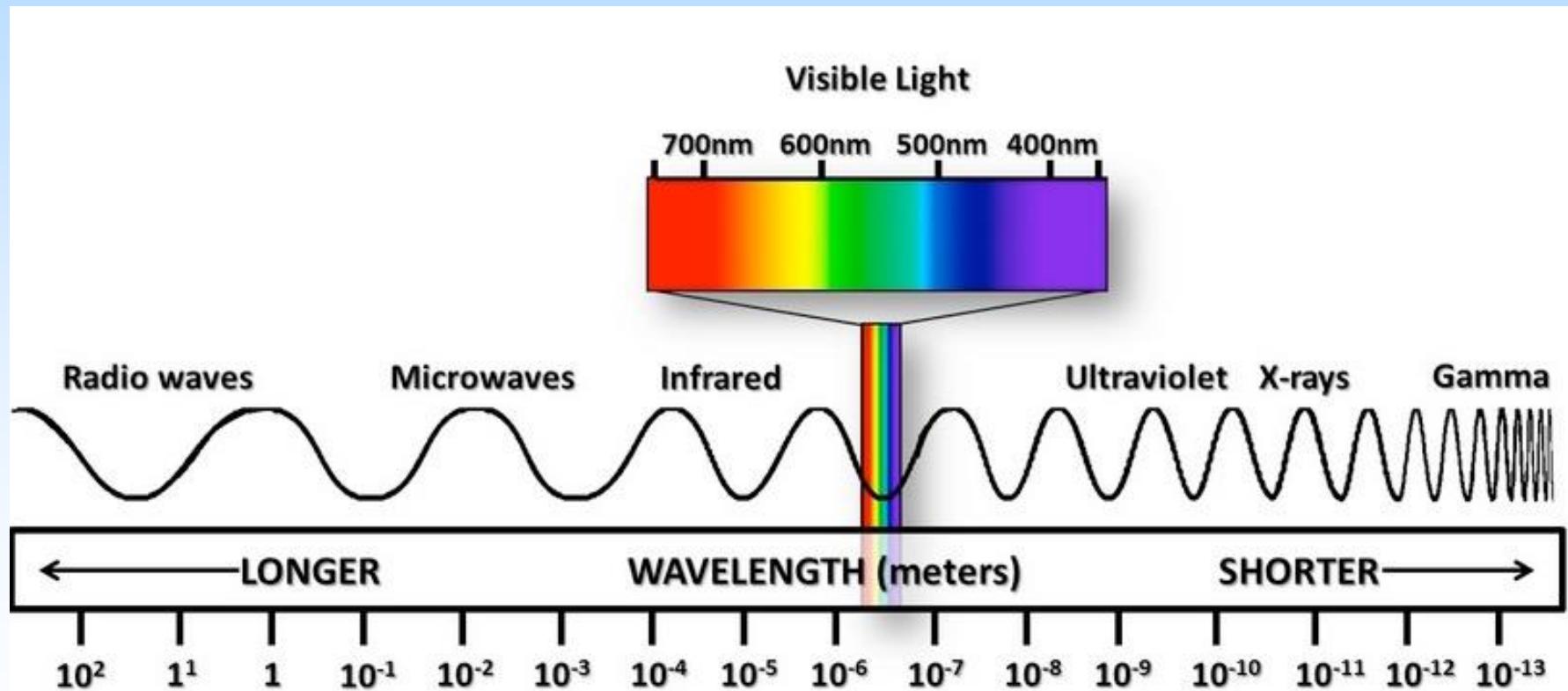
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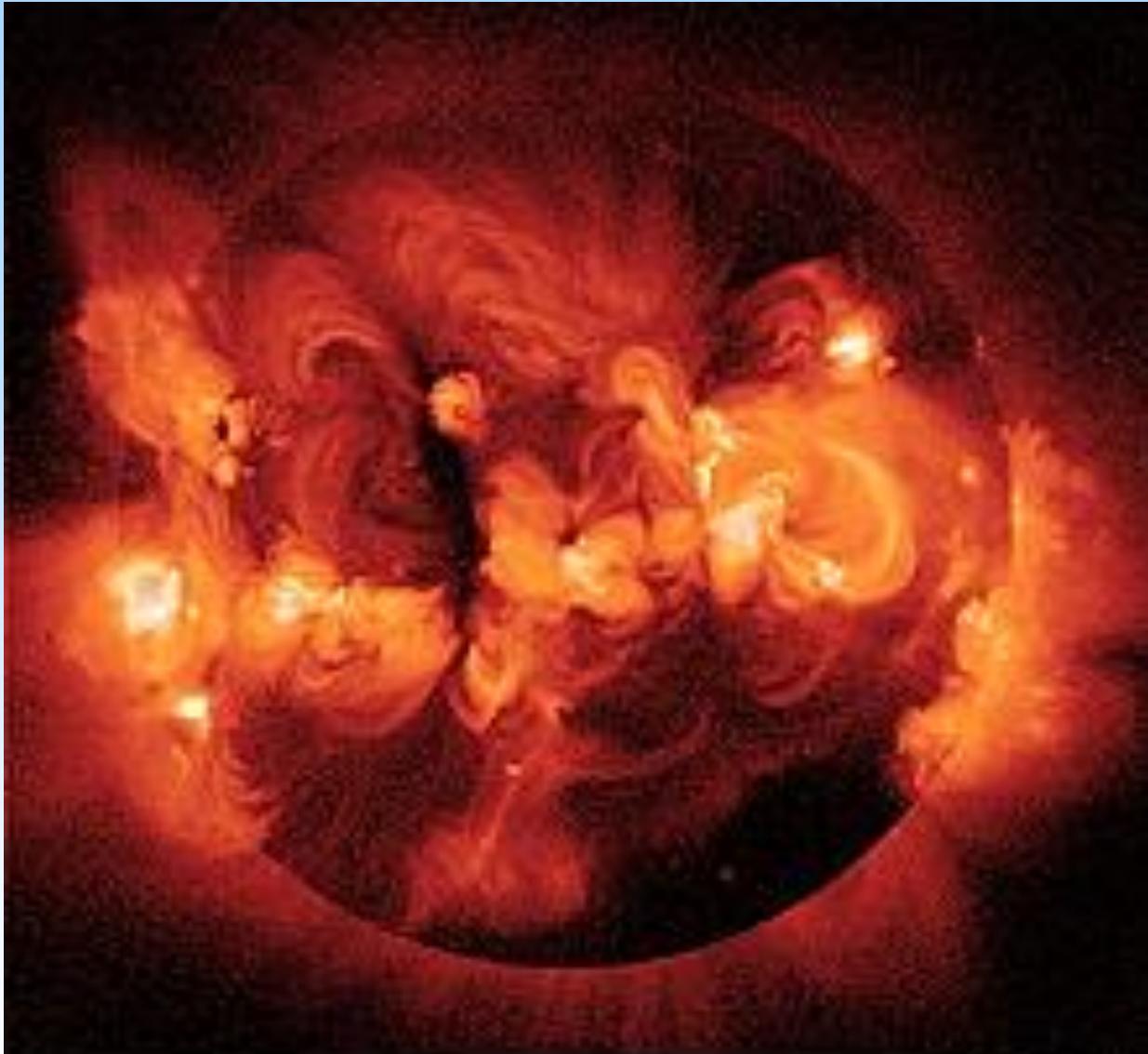






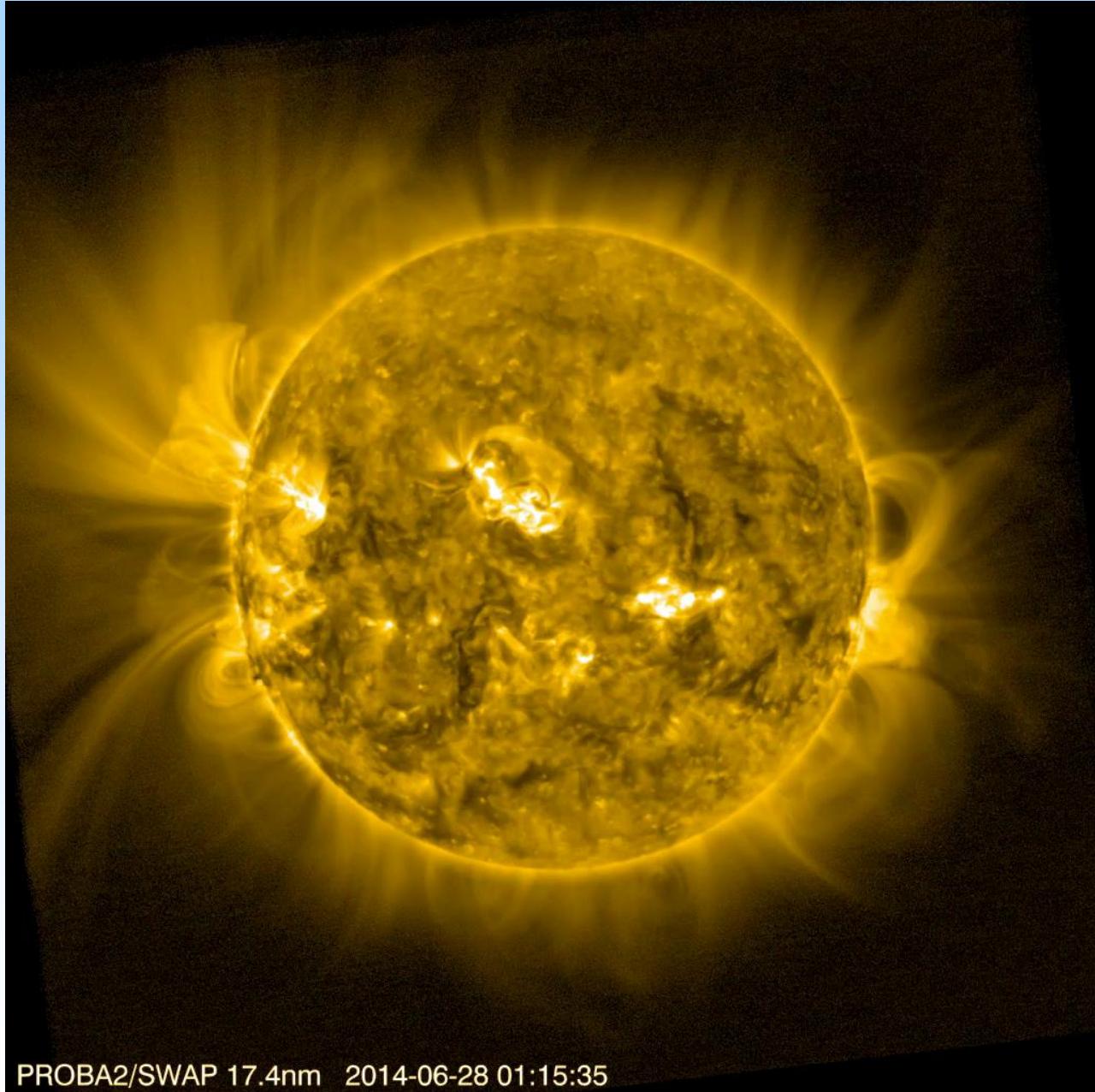
We have to go to *space* to see the Sun's outer atmosphere with regularity.





NASA

The Corona from Yohkoh/SXT



PROBA2/SWAP 17.4nm 2014-06-28 01:15:35

# The Corona

- Expected to be cool, but found strange spectral lines, first during 1869 eclipse.
- Many explanations considered, including a “new” element: *coronium*.
- **But this didn’t work....**

# Annular Eclipse (2012)